Spectrum for Body Sensor Networks
GE Healthcare Monitoring Solutions

Presentation to the FCC

ET Docket No. 06-135

July 24, 2007

imagination at work

Meeting objective

"GE Healthcare urges the Commission to move expeditiously by preparing a Further Notice which will propose the new spectrum allocations and rule changes necessary to make the next generation of wireless medical devices a reality."

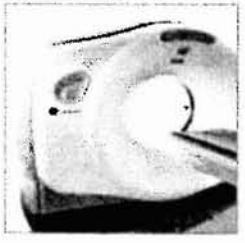
imagination at work

Agenda

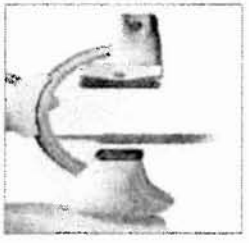
1. **GE Introduction**
2. **Body Sensor Networks**
   - Description and Benefits
   - Key Requirements
3. **Spectrum Request**
   - Band Limitations, Suggestions
   - Incumbents
4. **Feedback and Next Steps**

GE Healthcare

GE Healthcare is a $17 billion unit of General Electric Company. GE Healthcare employs more than 46,000 people in more than 100 countries.



Diagnostic Imaging



Surgery

Integrated Information Technology Solutions

Clinical Systems

LifeSciences

Medical diagnostics

Professional Services

Financial Services

GEHC Monitoring Solutions is an experienced industry leader in the development of seamless, wired and wireless connectivity and information distribution products and systems.

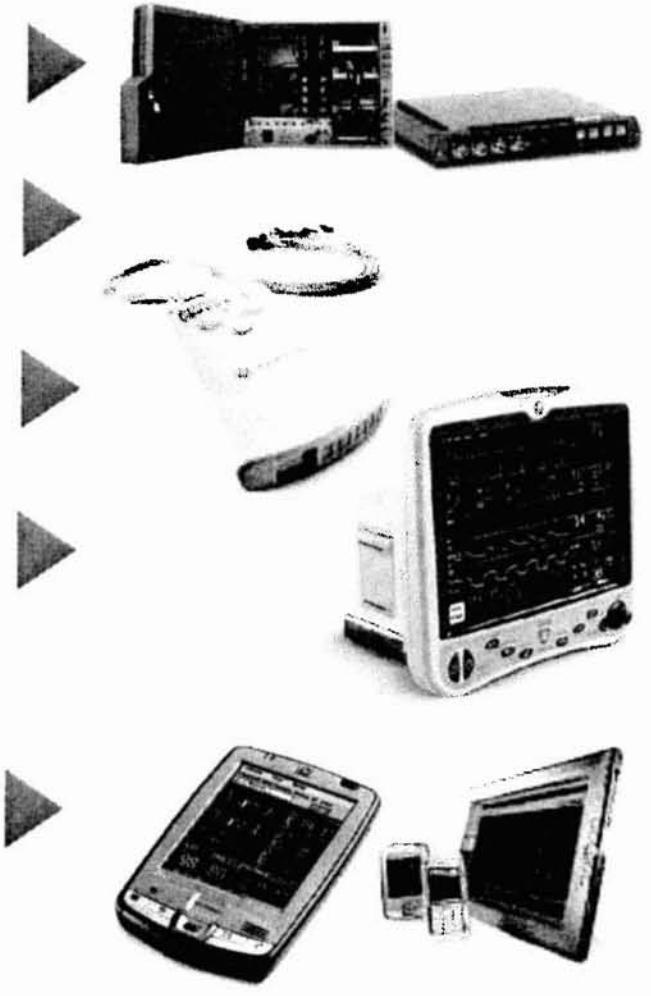
ApexPro CH **Ambulatory telemetry system operating in the WMTS.**

ApexPro FH **Frequency-hopping ambulatory telemetry system operating in the WMTS.**

DASH patient monitor **Delivers basic vital signs to ICU monitoring units with built-in wireless LAN.**

Web and Mobile Viewer **Provides clinician access to patient data via wireless LAN or cell phone.**

Enterprise Access **Multi-use wireless infrastructure (600 MHz – 6 GHz) extends clinical, voice and business application access throughout the enterprise.**



Challenges to Healthcare

- An aging population
- Sicker, higher acuity patients
- Staff overload and fatigue
- Quality and safety imperatives
- EMR directives
- Tightening margins

Healthcare challenges

Hospital Acuity is Rising	• As the population ages, the average acuity of hospitalized patients will increase rapidly. [1] • In one survey, hospital acuity grew 21% over 5 years. [2]
Skilled Labor is Becoming Scarce	• The US is expected to have a shortage of 1 million registered nurses in 2020. [3] • By 2020, the number of doctors specializing in treating critically ill patients in the US likely will not meet the demands of an aging population. [4]
Reporting Requirements are Significant	• Currently, hospitals must manage more than 300 external reporting requirements. • In a typical hospital, 40% of patient care time for each active bed is spent manually recording patient information.[5]
Next Generation Patient Monitoring Systems Could Play a Role	• 10% of all US hospital beds are located in ICUs. • Adults in the US receive only about 55% of recommended care for a variety of common conditions. [6] • US demand for patient monitoring systems will grow 5.4% annually through 2010, bolstered by technology advances. [7]

[1] "The Critical Care Workforce: A Study of the Supply and Demand for Critical Care Physicians." Requested by: Senate Report 108-81
[2] Unruh L. Licensed nurse staffing and adverse outcomes in hospitals. Med Care (AHRQ and NSF study). 2003.
[3] U.S. Department of Health and Human Services.
[4] "The Critical Care Workforce: "A Study of the Supply and Demand for Critical Care Physicians," Health Resources and Services Administration. 22 May 2006
[5] "ICU Data Center, Inc."." University of Florida Office of Technology Licensing October 2006.
[6] "Agency for Healthcare Research and Quality: Frequently Asked Questions." AHRQ. United States Department of Health and Human Services.
[7] "Patient Monitoring Systems to 2010." The Freedonia Group. 1 May 2006.

GEHC Monitoring Solutions Vision

Every patient's monitoring needs will be met, in or out of the hospital.

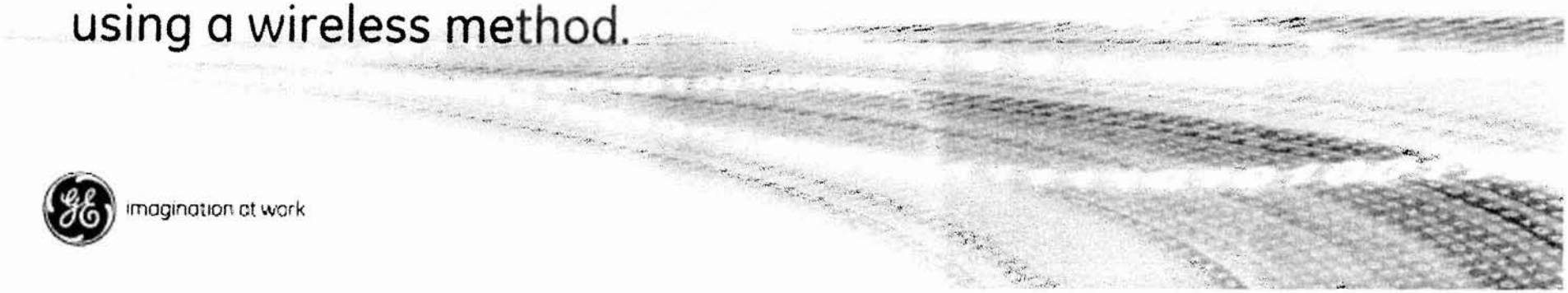
False and nuisance alarms will be eliminated.

The majority of measurements will be taken by non-invasive, miniaturized devices and, when possible, these devices will communicate using a wireless method.

Clinicians will always have access to care-critical information.

Enterprise-wide patient surveillance will be routine.

Workflow patterns will be tracked, analyzed and continuously improved.



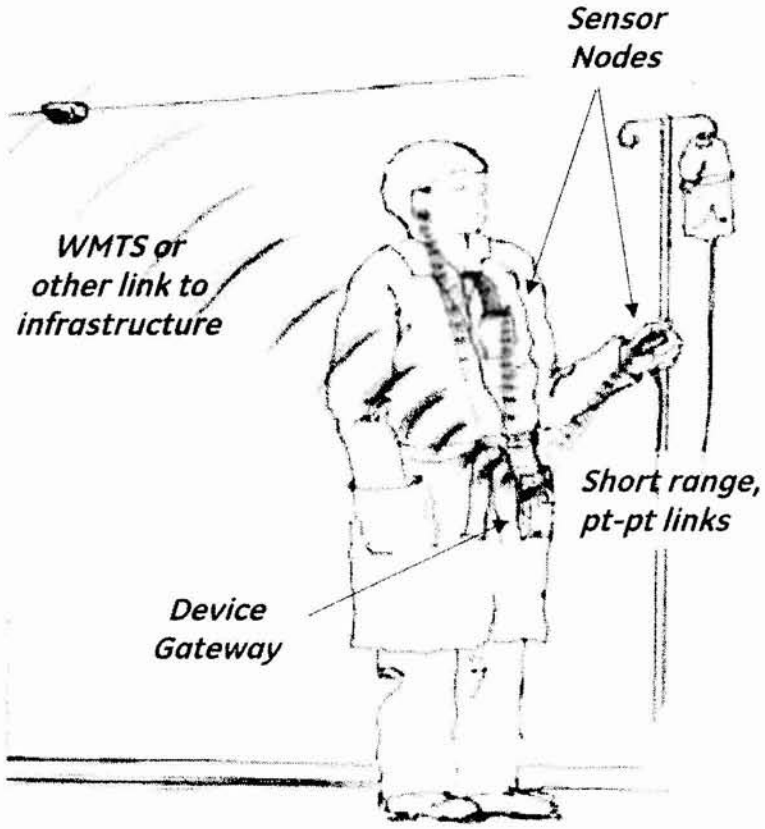
imagination at work

Body Sensor Network (BSN) for medical monitoring

Provides a wireless network of sensors around a patient.

Clinical Benefits

- Patient mobility, comfort, infection control
- Monitoring flexibility and scalability
- Extension of monitoring into care areas that are currently unmonitored
- Reduced clinical errors
- Reduced overall monitoring costs



Medical BSN sensor types

Sensor data rate

- Individually ~ 1-2 kbps per sensor
- Aggregate ~ 10+ kbps per patient

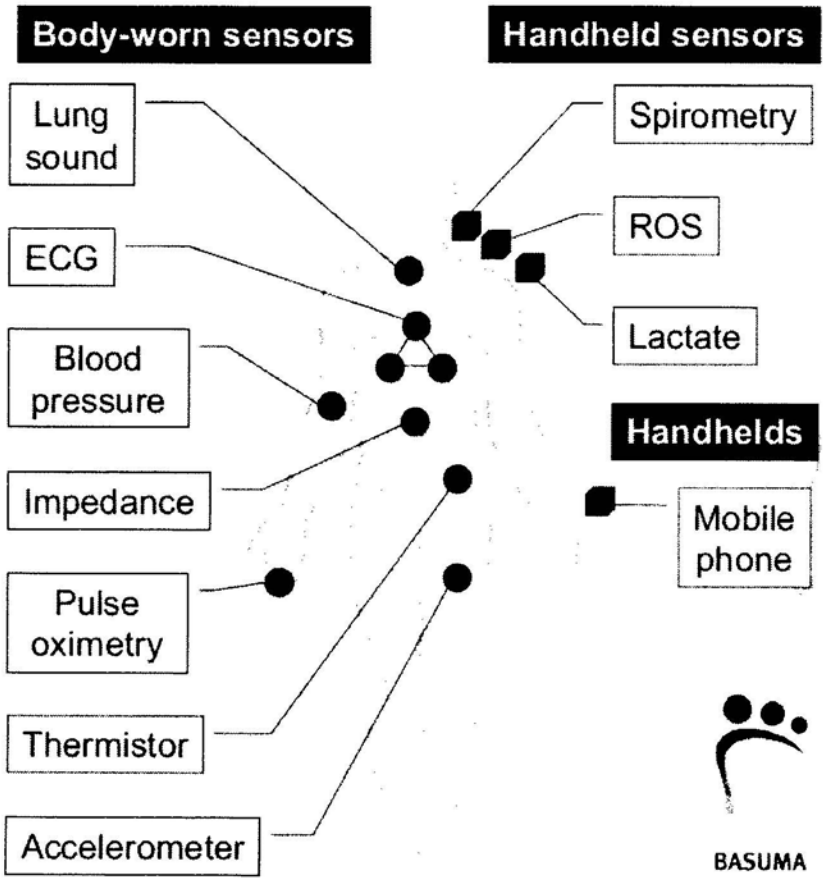


Image from "BASUMA - the sixth sense for chronically ill patients" by Falck, T.; Espina, J.; Ebert, J.-P.; Dietterle, D. Wearable and Implantable Body Sensor Networks, 2006. BSN 2006. International Workshop on, Vol., Iss., 3-5 April 2006.

GEHC's primary focus for BSN use will be in clinical environments, but other settings should also be allowed.

Hospital

- ER, OR, ICU
- Ambulatory, maternity
- Sleep study, etc.

Expanding Beyond Hospital

- Ambulance
- Physician office
- Home
- School and Office
- First responders
- Military







Significant BSN activity, beyond GEHC

Activities

Academic and industrial

- Imperial College London, Univ. of Birmingham, Queen Mary Univ. of London, Queen's Univ. Belfast, MIT, Harvard
- Continua Alliance, Intel, Philips, GE, others
- IEEE and IET conferences and seminars

DARPA solicitation

- Sensor Tape wearable sensors for war fighter physiological triage and monitoring

IEEE 802.15 WPAN

- MBAN study group for medical body area networks active

European Union funding

- MyHEART body worn, textile electronics for cardiovascular disease detection (€32.9M)
- BASUMA medical application BSN (€8.9M)

Enabling Technology Development

- On-body RF propagation
- Body worn antennas
- CMOS radio devices
- Sensor network protocols
- Electronic miniaturization
- Low power electronics
- Power harvesting
- Textile electrodes
- Context aware sensor algorithms
- Clinically tested user interface

Technical challenges for use of BSNs in a clinical environment

Robust wireless link for unprocessed medical monitoring data

- Bounded rates of latency and data loss require diversity techniques, error correction mechanisms

Capacity for many collocated patients, each with many sensors

- Patient's aggregate sensors may require > 10 kbps data rate
- Autonomous, distributed control desired for each BSN

Coexistence with other radio devices

- Frequency agility, short messages and brief channel occupancy

Battery powered for several days of continuous operation

- Large bandwidth for duty cycle, TDMA

Miniaturized, body-worn sensor devices

- Small antennas are more efficient at higher efficiencies.

Clinical BSNs require protected spectrum

Current spectrum cannot accommodate BSN devices

Unlicensed Bands

- Part 15 lacks protection from interference
- Very difficult to ensure reliability needed for unprocessed, life-critical monitoring data
- Impossible to anticipate variety of unlicensed devices – today and tomorrow
- Hospitals have limited control of their RF spectrum
- Hospitals fully utilize 2.4 GHz WLAN for mission critical applications

400 MHz MedRadio

- Proposed 0.1% duty cycle limit of wing bands force BSN to 3 MHz center of MedRadio band
- 3 MHz insufficient for BSN patient population within hospital
- BSNs require 1 MHz per channel to support data rates and required error control mechanisms, and to make multiple sensors possible

WMTS

- Spectrum currently used for ambulatory monitoring – intended for BSN backhaul
- Insufficient WMTS spectrum to support BSNs in addition to traditional telemetry systems
- Coordination by frequency rules do not accommodate frequency agile BSNs
- Limits BSN deployment to hospitals; prohibits use in ambulance, home, office
- Impractical to design low cost/disposable devices for UHF and L band – neither supported by COTS transceivers

" For the benefits of BSNs to become a reality, additional spectrum will need to be designated specifically for this purpose."

Permitted devices should be limited to monitoring, diagnosing or treatment of a patient

Rules should permit use outside of health care facilities

- Patient homes, physician offices, ambulances

Spectrum need not be entirely contiguous

- If shared spectrum, larger block needed to ensure availability and reliability

Licensed-by-rule approach is preferable

- Secondary allocation acceptable; unlicensed is feasible as special purpose band

Hospital patient population and sensor use cases require minimum of 10 MHz of available and usable spectrum at any given time, excluding spectrum in use by incumbents

- 10 MHz at any given time should be sufficient to support most patient/sensor density scenarios
- Mobility of patients requires frequency agility and diversity

On-body propagation supports short range, low power links

- Emissions about –30 to -10 dBm EIRP for operation over 400 to 2400 MHz range

Ability to leverage commercially available radio components enables low-cost BSNs and commercial acceptance

The proceeding record supports a new spectrum allocation suitable for BSN devices.

- Comments filed by Medtronic, Intel, and AMI Semiconductor (AMIS) discuss monitoring applications similar to GEHC's BSNs.
- Alfred Mann Foundation (AMF), Medtronic, and Partners HealthCare state that additional spectrum should be allocated.
- AMF states that the proposed MedRadio band is insufficient for high bandwidth applications like their wideband microstimulator and that WMTS is too congested.
- NDI Medical states that MedRadio device communications should not be limited to healthcare facilities.
- Cleveland FES Center describes a similar high bandwidth / low latency application.
- Partners HealthCare states that WMTS systems are currently at capacity and 2.4 GHz band devices are rapidly proliferating in the hospital, posing a capacity and QOS challenge.
- AMIS discusses the potential for simple, even disposable, wireless devices to reduce health care costs and improve care.

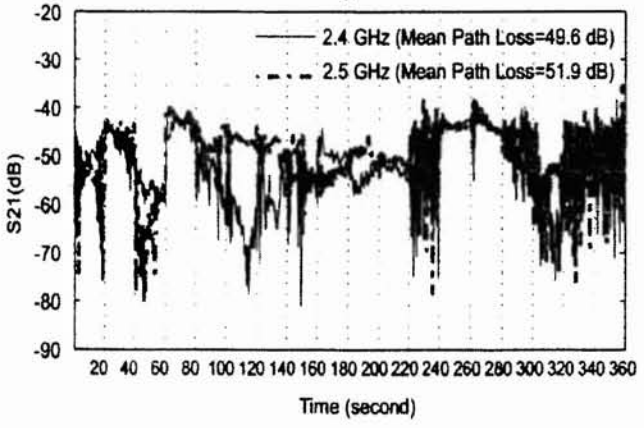
Key Considerations for Spectrum Allocation

- Ensure that sufficient spectrum is available despite secondary status and the nature of incumbent use
- Avoid capacity constraints within high patient density environments
- Contention-based protocol constraints
- Power consumption constraints
- Reliability of the RF link with multiple sensors
- Economy-of-scale considerations / cost of equipment components

"GEHC expects that BSN devices will operate with maximum emissions in the range of –30 dBm for operations at 400 MHz , and –10 dBm EIRP for operations at 2300 MHz."

Path loss variation from body posture and movement indicates a need for a 20 dB margin at 2300 MHz.

Path loss between printed monopoles on left waist and right chest



[Ref]: *Parametric Study of Wearable Antennas with Varying Distances from the Body and Different On-Body Positions*, Alomainy, A.; Hao, Y.; Davenport, D.M. , Antennas and Propagation for Body-Centric Wireless Communications, 2007 IET Seminar on, Vol., Iss., 24-24 April 2007.

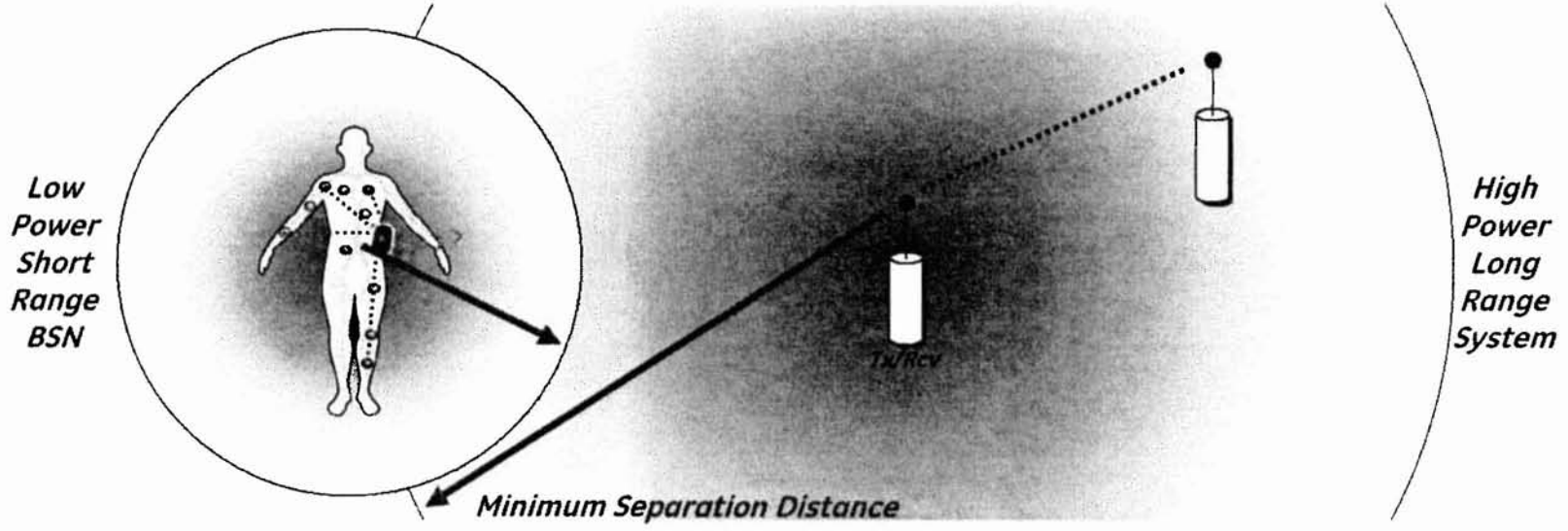
Link Budget

	nRF24L01	CC1100
Frequency (MHz)	2400	433
Data Rate (kbps)	1000	500
Transmit Power (dBm)	-7	-20
Transmit Power (mW)	0.20	0.01
Antenna Gain (dBi)	0	0
Antenna Loss (Efficiency) (dB)	-3	-6
EIRP (dBmW)	-10	-26
Mean On-body Path Loss (dB)	-50	-36
Mean Received Signal Power (dBm)	-63	-68
Sensitivity for 10^{-3} BER or 1% PER (dBm)	-85	-88
Received Signal Margin (dB)	22	20

Sharing spectrum between BSN devices and incumbent high power, long-range (HPLR) systems

Engineering Analysis Approach:

The undesired transmitter must be sufficiently separated from the victim receiver such that the power of the undesired signal in the bandwidth of the victim receiver measured at the victim antenna is at most equal to the thermal noise power of the victim receiver plus the noise figure of the victim receive chain.



Risk of BSN interference to HPLR operations mitigated by BSNs' low power, spatial separation

Case 1: BSN = jammer, HPLR = victim

Frequency	ERP	Min Separation Distance	
		Free space, n=2	Building, n=3
430 MHz	-30 dBm	140 m	11 m
2400 MHz	-10 dBm	250 m	9 m

NF = 15 dB, B = 1 MHz

Case 2: BSN = victim, HPLR = jammer

Frequency	ERP	Min Separation Distance	
		Free space, n=2	Building, n=3
430 MHz	25 dBm	10 km	100 m
2400 MHz	25 dBm	56 km	560 m

B = 1 MHz, Sensitivity = -85 dBm, SNR = 10 dB

Interference will be observed at BSN before HPLR

Case 2 separation > Case 1

GEHC proposes the following frequency bands as candidates for medical BSNs:

2360 - 2395 MHz

2395 - 2400 MHz

410 - 450 MHz

2300 - 2305 MHz

2495 - 2496 MHz

Incumbents in bands proposed by GEHC
2360–2395 and 2395-2400 MHz

2360-2395 MHz

- Federal and non-Federal aeronautical telemetry and telecommand
- Primary amateur operations, including fast-scan TV, high rate data and control – not weak signal operations
- Adjacent ISM at 2400 MHz and radio astronomy at 2380 MHz

2395-2400 MHz

- Primary amateur operations, including fast-scan TV, high rate data and control – not weak signal operations

BSN coexistence mechanisms

- Commission has stated that aeronautical mobile use will be predominantly at remote facilities and at high altitudes such that the potential for interference from terrestrial services sharing the band is small given "high elevation and off-axis attenuation of high gain flight testing receive antennas on the ground." - *FCC 04-246, Docket Nos. 00-258 and 02-8*
- BSNs pose minimal risk of interference to high-power, long range (HPLR) operations given their low power and frequency agility.

Incumbents in bands proposed by GEHC
410–450 MHz

410-420 MHz

- Narrowband Federal LMR at and in vicinity of their stations
- NASA space-to-space communications
- Hydrological telemetry

420-450 MHz

- Federal radar systems
- Secondary amateur services

BSN coexistence mechanisms

- BSNs could share with Federal systems in this band just as NTIA noted that amateurs have "successfully co-existed with Federal fixed, mobile and radiolocation services for nearly fifty years... primarily due to the fact that much of the Federal spectrum usage is located away from populated areas." – *NTIA Federal Long Range Spectrum Plan, Sept 2000*
- BSNs pose minimal risk of interference to high-power, long range (HPLR) operations given their low power and frequency agility.
- ARRL has acknowledged that amateur operations in other bands could successfully coexist with "low powered devices that operate over short distances" – *ARRL, RM-10165, May 2001*

Incumbents in bands proposed by GEHC
2300-2305 and 2495-2496 MHz

2300-2305 MHz

- No primary service
- Need to protect sensitive NASA receivers at Goldstone, CA
- Amateur radio secondary status

2495-2496 MHz

- No service allocation - guard band between satellite and Broadband Radio Service operations

BSN coexistence mechanisms

- BSNs satisfy NTIA's criteria for non-interference to NASA operations – *NTIA Spectrum Reallocation Final Report, 1995*
- ARRL has acknowledged that amateur operations in this band could successfully coexist with "low powered devices that operate over short distances." – *ARRL, RM-10165, May 2001*
- BSNs pose minimal risk of interference to high-power, long range (HPLR) operations given their low power and frequency agility.

Conclusion

GE Healthcare requests that the FCC issue an NPRM proposing a suitable spectrum designation for BSNs.

Thank you